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ABSTRACT. Using firm-level data on the Japanese manufacturing industry, this study identifies the causal effect of uncertainty on the dynamic relation between corporate investment and financing conditions. It demonstrates that the cautionary effect is increasingly dominant under high uncertainty irrespective of the type of corporate investment—capital investment and R&D—and that this result remains even in the weak instrument robust inference. Hence, the dominance of the cautionary effect over the financing constraint effect makes actual corporate investment decisions under high uncertainty indifferent to the firm's financing conditions.

JEL classification: G01, G31, G32.

Keywords: uncertainty shock; capital investment; R&D; sensitivity to internal and external financing; system GMM; weak instruments.

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1. Introduction The countercyclical behavior of economic variables such as business profits, labor income, and productivity reflects the swings in economic uncertainty (see Bloom (2014) for a survey of the theoretical and empirical literature). How increasing uncertainty affects the dynamics in the business cycle has traditionally been analyzed within the framework of irreversible investment (Abel (1983), Bernanke (1983), Abel and Eberly (1994; 1996), Caballero (1999), Cooper and Haltiwanger (2006), Bloom (2007; 2009) and Bachmann et al. (2013a)). This approach considers a firm's future investment opportunities to be the real option. In other words, when making investment decisions under high uncertainty, firms should wait until such uncertainty is resolved and the project is more clearly successful or not.

On the contrary, spurred by the drastic increase in asset price volatility and the credit crunch during the 2007–09 financial turmoil, an emergent body of the macroeconomic literature has emphasized financial frictions as an additional channel through which volatility fluctuations have substantially unfavorable effects on the macroeconomy (Brunnermeier and Sannikov (2014), Christiano et al. (2014) and Gilchrist et al. (2014)). This approach predicts that increased uncertainty raises the user cost of capital, or the agency cost (Bernanke et al. (1996) and Kiyotaki and Moore (1997)), through the interaction between the heightened uncertainty and financial market frictions, thus leading firms with higher agency costs to delever and inducing a decline in investment spending by firms with internal financing constraints.

This empirical study contributes to both these strands of the literature on firm investment under high uncertainty. It uses firm-level consolidated data on the Japanese manufacturing industry from fiscal years 2001 to 2014 to empirically examine their theoretical predictions in terms of whether and how investment sensitivity to a firm's financing conditions depends on fluctuations in uncertainty. While the two strands of the literature on uncertainty and investment dynamics agree that uncertainty distorts the level of corporate investment through the cautionary and/or the financial friction channel, Bloom (2014) highlights not only this level effect, but also a *sensitivity effect* that has received little attention in the extant literature. We empirically test this sensitivity effect by focusing on the role of a firm's internal and external financing constraints through which fluctuations in uncertainty affect corporate investment dynamics.

To investigate whether and how fluctuations in uncertainty influence the sensitivity dynamics (i.e., the impulse response of corporate investment to a marginal change in a firm's internal and external financing), we adopt a two-step approach to control for the endogeneity of uncertainty. In the first step, we extract the purely exogenous shocks from the firm- and macro-level uncertainty measures based on stock price volatility and the news source of Japanese economic policy. This extraction of the uncertainty shocks prepares for a randomized experiment followed by the second step: we include those uncertainty shocks in a corporate investment equation with the interaction term of the uncertainty shocks and a firm's financing variables such as cash flows and debt issues. Through these empirical steps, we set up a quasi-natural experiment with a randomized shock of uncertainty to identify the dynamics in the causal link between uncertainty and investment–financing sensitivity, particularly focusing on the interaction effect. Furthermore, we conduct the weak instrument robust inference based on the Kleibergen (2005) testing procedure to complement our causal analysis.

In the empirics, we provide two types of predictions about the dynamics in investment–financing sensitivity in association with the level of uncertainty. According to the macroeconomic literature emphasizing the interaction effect between financial frictions and uncertainty, high uncertainty limits a firm's debt capacity because such heightened uncertainty—under limited liability—favors its shareholders over its bondholders, thus inducing a decline in the value of debt claims, exacerbating the debt overhang problem, and increasing the cost of capital (see also Merton (1974) and Nakashima and Saito (2009)). This theoretical insight is followed by the prediction that high uncertainty increases the sensitivity of corporate investment to financing variables, particularly internal financing ones, as dependence on internal financing becomes larger because of the increase in the cost of external financing and resulting severity of financing constraints.

The second prediction is an extension of the traditional wait-and-see effect under high uncertainty. High uncertainty makes managers less sensitive to changes in the fundamental economic conditions, including the cost of capital (see Bloom (2007; 2014), Bloom et al. (2007), Drobetz et al. (2018) and Alfaro et al. (2019)). From this viewpoint, the strength of the relation between corporate investment and the cost of capital (i.e., the dependence of internal financing or its premium over external financing) will be decreasing in uncertainty, even though firms face a higher cost of capital. This financial aspect of the cautionary effect because of a firm's unresponsiveness to financing conditions leads to the prediction that high uncertainty decreases investment sensitivity to both internal and external financing variables; put differently, a firm's financing constraints are indifferent to corporate investment decisions under high uncertainty because of the dominance of the cautionary effect over the financing constraint effect.[1]

Given these two predictions about how changes in uncertainty can amplify corporate investment by affecting a firm's financial decisions, this study focuses on two types of corporate investments: capital investment and research and development (R&D). As pointed out in the empirical and theoretical literature, R&D spending is more affected by a firm's financing constraints than capital investment is (Himmelberg and Petersen (1994) and Czarnitzki and Toole (2011)) and uncertainty has a different impact on the dynamics of capital investment than R&D because of the presence of different adjustment costs (Bloom (2007)). In this study, focusing on Japanese manufacturing firms making both types of investments, we uncover the different characteristics of the dynamics in their sensitivity to financing constraints under high uncertainty.

Our empirics also aim to contribute to the literature on investment–cash flow sensitivity. The study of investment–cash flow sensitivity constitutes one of the largest bodies of the literature in corporate finance. Some studies have questioned the interpretation of investment–cash flow sensitivity as a measure of a firm's constraints on external financing such as debt and stock issuance.[2] However, these empirical studies neither focus on nor

[1] Bloom (2007) and Bloom et al. (2007) note this dominance of the cautionary effect on corporate investment decisions under high uncertainty over the direct effects of changes in economic and financial conditions, through which firms appear to be less responsive to any given fundamental shock.

[2] For example, Kaplan and Zingales (1997) study firms classified as financially constrained by Fazzari et al. (1998) and find that firms that appear less constrained actually exhibit greater investment–cash flow sensitivities. More recently, Chen and Chen (2012) also find that investment–cash flow sensitivity is zero—even during the U.S. credit crunch—and suggest that investment–cash flow sensitivity is a poor measure of financing constraints. Brown and Petersen (2009) show that investment–cash flow sensitivity largely disappears for capital investment, but remains comparatively strong for R&D investment, even though it is declining over time.

control for the effect of the uncertainty faced by firms. Considering that many studies have used investment–cash flow sensitivity despite the controversy about the interpretation of external financing constraints based on the agency problem (see Hoshi et al. (1991), the references in Hubbard (1998), and, more recently, Moyen (2004), Biddle and Hilary (2006), Almeida and Campello (2007), Beatty et al. (2010), and Abel (2017)), the implication of investment–cash flow sensitivity should be reassessed in terms of uncertainty. This study provides evidence that helps settle the debate, considering the difference between capital investment and R&D.

In the next section, we briefly review the literature on the relation between uncertainty and corporate investment. Section 3 discusses our framework for the identification and uncertainty measures. Section 4 presents our empirical model and method, defines the variables, describes the data sources, and calculates the summary statistics. Section 5 shows the estimation results for capital investment and R&D spending. Section 6 concludes.

2. Uncertainty and Corporate Investment Our empirical study builds on a growing empirical literature documenting that uncertainty countercyclically affects economic outcomes.[3] In particular, uncertainty has been shown to affect long-run economic growth (Baker and Bloom (2013) and Nakamura et al. (2017)), bank liquidity creation (Berger et al. (2017)), business cycles (Stock and Watson (2012), Bloom et al. (2016) and Basu and Bundick (2017)), and equity prices as well as risk premiums (Pástor and Veronesi (2012; 2013), and Brogaard and Detzel (2015)).

Complementing this aggregate-level evidence, several studies find that uncertainty affects firm-level outcomes such as capital investment (Dixit and Pindyck (1994), Ogawa and Suzuki (2000), Bloom et al. (2007), Bloom (2009), Caglayan and Xu (2014), Gulen and Ion (2016) and Kim and Kung (2017)), R&D investment (Bloom (2007), Bologna (2016) and Stein and Stone (2019)), firm risk taking (Akey and Lewellen (2017)), equity issuance (Colak et al. (2016) and Jens et al. (2017)), and the cost of corporate debt (Waisman et al. (2015)). Overall, both aggregate- and firm-level empirical evidence suggests that uncertainty has an unfavorable effect on the economy by affecting corporate decisions.

[3] See Bloom (2014) for a survey of this literature.

As discussed in the Introduction, this study contributes to two strands of the literature examining the effect of uncertainty on corporate investment. The first strand analyzes how high uncertainty influences investment dynamics within the framework of irreversible investment (Abel (1983), Bernanke (1983), Abel and Eberly (1994; 1996), Caballero (1999), Cooper and Haltiwanger (2006), Bloom (2007; 2009) and Bachmann et al. (2013a)). This approach treats the firm's future investment opportunities as real options and emphasizes the importance of the wait-and-see effect. In response to increased uncertainty, firms wait and see until uncertainty is resolved and the project is more clearly successful or not.[4]

The second strand is a stream of the macroeconomic literature that has pointed to financial market conditions and emphasized the role of agency costs as an additional channel through which volatility fluctuations can affect investment dynamics. See Bernanke et al. (1996) and Kiyotaki and Moore (1997) for seminal works emphasizing the role of agency costs in firm investment. The emergent DSGE literature emphasizing the role of uncertainty includes Brunnermeier and Sannikov (2014), Christiano et al. (2014), and Gilchrist et al. (2014). Based on Merton's (1974) option pricing insight into the relation between uncertainty and the value of debt claims, this literature focuses on the financial channel through which greater downside risk limits a firm's debt capacity because heightened uncertainty favors the firm's shareholders over its bondholders under limited liability, thereby inducing a decline in the value of debt claims and exacerbating the debt overhang problem (see also Nakashima and Saito (2009)). By doing so, this approach analyzes the implications of the interaction between the traditional irreversible investment problem and debt overhang problem.

While the literature accepts the common view in that uncertainty distorts the level of corporate investment through the cautionary and financial friction channels, Bloom (2014) highlights not only this level effect, but also a sensitivity effect that has received little attention in the extant literature. We empirically test this sensitivity effect by focusing on the role of a firm's financing conditions through which fluctuations in uncertainty amplify

[4] However, the wait-and-see effect of uncertainty on corporate investment in the presence of irreversibilities is theoretically ambiguous. For example, Abel (1983) and Bloom (2007) demonstrate that the effect depends on assumptions about the types of capital expenditure, initial accumulation of capital, and market structure.

corporate investment dynamics by affecting corporate decisions. More concretely, we examine whether and how fluctuations in uncertainty increase or decrease the dynamic relation between a firm's investment spending and financing conditions.

From the viewpoint of types of corporate investments, several studies point to the noticeable difference between capital investment and R&D in their dynamics.[5] Placing cash flows at the center of the identification strategy for a firm's financing constraints and financing distress, empirical analyses of the R&D investment–financing constraints relationship have demonstrated that this relation is substantially stronger than that with capital investment (Himmelberg and Petersen (1994) and Czarnitzki and Toole (2011)), even though it gradually declines over time (Brown and Petersen (2009)). Moreover, R&D investment–cash flow sensitivity is more pronounced in younger and smaller firms (Brown et al. (2009; 2012) and Hall et al. (2016)). In the context of the dynamic relation between uncertainty and corporate investment, uncertainty induces a different impact on the dynamics of capital investment and R&D because of the different structure of adjustment costs (Bloom (2007) and Bontempi (2015)). In this study, focusing on Japanese manufacturing firms making both types of investments, we uncover the different features of the dynamics in their sensitivity to financing constraints under high uncertainty.

3. Identification of Dynamic Effects and Uncertainly Measures

In this section, we start by considering a framework for identifying the dynamic causal effect of uncertainty on corporate investment through a firm's financing conditions and then discuss the uncertainty measures used for the causal identification.

3.1. Identification Framework

To identify the dynamic causal effect of uncertainty on corporate investment through financing conditions, we assume the following dynamic system based on linear functions g:

$$\mathrm{I}_{i,t} = g_1\left(\mathrm{I}_{i,t-1}, f_{i,t}, f_{i,t} * \mathrm{U}_{i,t}, \mathrm{Others}^{\mathrm{I}}_{i,t}\right), \tag{1}$$

$$f_{i,t} = g_2\left(f_{i,t-1}, \mathrm{I}_{i,t}, \mathrm{U}_{i,t}, \mathrm{Others}^{f}_{i,t}\right), \tag{2}$$

[5] See Hall and Lerner (2010) for a survey of this literature.

$$\mathrm{U}_{i,t} \quad = \quad g_3\left(\mathrm{U}_{i,t-1}, \mathrm{I}_{i,t}, f_{i,t}, \mathrm{Others}^{\mathrm{U}}_{i,t}\right), \tag{3}$$

where $\mathrm{I}_{i,t}$ is investment spending, including capital investment and R&D, for firm i in period t. $\mathrm{U}_{i,t}$ denotes a firm-level measure for the uncertainty faced by each firm in period t.[6] f_t represents a financial variable for the internal and external financing of corporate investment such as cash flows and debt issuance. $\mathrm{Others}_{i,t}$ in equations (1)–(3) represents other factors that can determine a firm's investment and financing decisions as well as the level of uncertainty. Investment equation (1) includes an interaction term $f_{it} * \mathrm{U}_{i,t}$ to capture the effect of uncertainty through a firm's financing conditions. Equations (1) to (3) have a linear dynamic structure with one-lagged dependent variables.[7]

This study identifies the dynamic causal link between the financing variable and corporate investment $f_{i,t} \rightarrow \mathrm{I}_{i,t+k}$ $(k = 0, \ldots, \infty)$ in an uncertain environment $\mathrm{U}_{i,t}$, using the interaction effect in investment equation (1). To this end, we need to estimate investment equation (1) by controlling for the dynamics in $f_{i,t}$ and $\mathrm{U}_{i,t}$, each represented in equations (2) and (3).

To control for the dynamics in uncertainty $\mathrm{U}_{i,t}$ expressed in equation (3), we construct an uncertainty shock $\mathrm{U}^s_{i,t}$ moving independently of the economic conditions—$\mathrm{I}_{i,t}$, $f_{i,t}$ and $\mathrm{Others}^{\mathrm{U}}_{i,t}$—and include this uncertainty shock in equations (1) and (2) as an uncertainty measure. Preparing for such an uncertainty shock, we set a quasi-natural experiment with a randomized shock of uncertainty to examine whether and how dynamic investment–financing sensitivity $f_{i,t} \rightarrow \mathrm{I}_{i,t+k}$ $(k = 0, \ldots, \infty)$ depends on the level of uncertainty in initial period t, particularly through the interaction effect of the financing variable and uncertainty shock $f_{it} * \mathrm{U}^s_{i,t}$.

Lastly, we run the Blundell–Bond (1998) system generalized method of moments (GMM) estimation for the dynamic panel investment model (1), preparing for appropriate instruments for the one-period lagged investment $\mathrm{I}_{i,t-1}$ and the financing variable $f_{i,t}$ to control for the dynamics of the financial variable in equation (2). In particular, to control for the

[6] Instead of firm-level uncertainty $\mathrm{U}_{i,t}$, we can include macro-level uncertainty U_t by considering the granular effect (Gabaix (2011)).

[7] One can include additional lags of corporate investment $\mathrm{I}_{i,t}$ in investment equation (1). However, we find that it does not qualitatively change the estimation results for the interaction effect reported in Section 5.

initial period effect of the uncertainty shock $\mathrm{U}^s_{i,t}$ on the financial variable in equation (2), we use this exogenous shock as the most important instrument. We employ the Blundell–Bond (1998) system GMM estimation as more persistent R&D spending, or a certain near random walk in it (see Section 5.2), could lead to substantial bias in the estimated coefficients when employing the Arellano–Bond (1991) GMM estimation. The Blundell–Bond (1998) system GMM estimation can ease this problem, even though it may still provide mixed results (see Blundell and Bond (1998)). Section 4 presents our specification of the investment model and instruments. In addition, we conduct the weak instrumental robust inference based on the Kleibergen (2005) testing procedure to complement our causal analysis (see Section 5.4).

3.2. **Uncertainty Shocks** As discussed above, a measure of exogenous uncertainty is necessary to identify the dynamic effect of uncertainty on corporate investment through a firm's financing conditions. In this subsection, we discuss such an uncertainty measure.[8]

3.2.1. **Firm- and Macro-Level Uncertainty** In this study, we focus on both firm-level and macro-level uncertainty. For firm-level uncertainty, we exploit information about the volatility of the daily excess equity returns of each firm. Equity volatility is calculated in the annualized standard deviation of daily excess returns, according to

$$\sigma^E_{i,t} = \sqrt{\frac{1}{D(t)-1}\sum_{d(t)=1}^{D(t)}\left(ER_{i,d(t)} - \overline{ER}_t\right)^2} \times \sqrt{D(t)}, \tag{4}$$

where i indexes firms and $d(t)$ ($d(t) = 1, \cdots, D(t)$) indexes trading days in firm i's fiscal year t. In equation (4), $ER_{i,d(t)}$ denotes the daily excess return of firm i defined as $ER_{i,d(t)} = R_{i,d(t)} - r^f_{d(t)}$, where $r^f_{d(t)}$ is the risk-free rate. For the risk-free rate, we use the daily return of newly issued 10-year Japanese government bonds.

As for macro-level uncertainty, we focus on the volatility index Japan (VIXJ) and

[8] Previous studies have employed various types of measures to infer fluctuations in uncertainty, including uncertainty measures based on the frequency of the uncertainty-related words or phrases that occur across a number of news sources (Baker et al. (2016)), the cross-sectional dispersion of survey-based business forecasts (Bachmann et al. (2013b)), and the common factor of the unforecastable component of a number of economic indicators (Jurado et al. (2013)).

economic policy uncertainty index for Japan (EPUJ). The VIXJ is provided by the Center of the Study of Finance and Insurance and is in strict accordance with the Chicago Board Options Exchange approach underlying the VIX. The EPUJ is the time-varying news-based index of Japanese economic policy uncertainty developed by Arbatli et al. (2017) and it is based on the frequency of articles in a country's major newspapers that focus on uncertainty about future economic policy, as proposed by Baker et al. (2016). We convert monthly data on the VIXJ and EPUJ into quarterly data by taking the average to estimate the uncertainty shocks, as we discuss in the next subsection. The uncertainty measures are calculated by taking the average for the fiscal year.

Figure 1 shows the firm- and macro-level uncertainty measures. For firm-level uncertainty, its sample average in each fiscal year is reported.

However, these uncertainty measures reflect the endogenously countercyclical effects of the economic and financing conditions faced by firms (see equation (3)); hence, their direct use leads to an erroneous evaluation of the causal effect of uncertainty on corporate investment. Therefore, we need to construct purely exogenous uncertainties moving independently of the economic and financing conditions. In the next subsection, we construct the uncertainty shocks.

3.2.2. **Exogenous Uncertainty Measures** Our estimate of exogenous firm-level uncertainty is based on the following three-step procedure suggested by Gilchrist et al. (2014). First, we remove the endogenous variation relating to the systematic risk in daily excess returns using the factor model:

$$ER_{i,d(t)} = \alpha_i + \beta_{\mathbf{i}}' \mathbf{f_{d(t)}} + u_{i,d(t)}, \tag{5}$$

where $ER_{i,d(t)}$ denotes the daily excess return of firm i and $\mathbf{f_{d(t)}}$ is a vector of the risk factors. To implement this first step, we employ the Fama and French (1992) three-factor model. For the three factors (i.e., the market, SMB, and HML factors), we use Kubota and Takehara's Fama–French data, compiled by Financial Data Solutions Inc.[9]

[9] In this compiled data for the three factors, the daily return of newly issued 10-year Japanese government bonds is used to calculate the market factor.

In the second step, we calculate the annualized firm-specific volatility of daily idiosyncratic excess returns:

$$\sigma_{i,t} = \sqrt{\frac{1}{D(t)-1}\sum_{d(t)=1}^{D(t)}\left(hatu_{i,d(t)} - \overline{u}_t\right)^2} \times \sqrt{D(t)}, \tag{6}$$

where $\hat{u}_{i,d(t)}$ denotes the OLS residual—the exogenous idiosyncratic return moving independently of the macro-level risk factors—from equation (5) and $\overline{u}_t$ is the sample mean of the exogenous return in a firm's fiscal year t.

Lastly, we assume that firm-specific idiosyncratic volatility follows the following autoregressive process:[10]

$$\ln \sigma_{i,t} = \gamma_i + \delta_i t + \rho \ln \sigma_{i,t-1} + \mathrm{U}^s_{i,t}, \tag{7}$$

where $\mathrm{U}^s_{i,t}$ denotes the idiosyncratic volatility shock. γ_i denotes the firm fixed effect used to control for the cross-sectional heterogeneity in $\sigma_{i,t}$, while the firm-specific term $\delta_i t$ captures the trends in idiosyncratic risk. To obtain the idiosyncratic volatility shock, we run the OLS estimation for the sample period from fiscal years 1978 to 2014.[11]

Our estimate of exogenous macro-level uncertainty is based on the structural vector autoregression (VAR) to identify an uncertainty shock as an exogenous movement in the VIXJ and EPUJ. Following Basu and Bundick (2017), we estimate a VAR with the following eight variables: one of the two uncertainty measures, gross domestic product (GDP), consumption, investment, a GDP deflater, stock price (Nikkei 225 index), and two measures of the monetary policy stance: the monetary base and short-term policy rate (overnight call rate). Since VIXJ and EPUJ data start in 1998 and 1988, respectively, we estimate the VAR using quarterly data over the 1998 and 2015 sample periods. With the exception of the uncertainty measures and short-term policy rate, all the other variables enter the VAR in log levels.

[10] The double-log specification of $\sigma_{i,t}$ reflects the fact that the firm-level idiosyncratic volatility of excess returns is highly positively skewed, a non-linear feature in which volatility has higher autocorrelation in a period of higher volatility.

[11] Following Gilchrist et al. (2014), we employ the OLS estimation because the average firm is in the long-term panel for more than 35 years, and hence the bias of the OLS estimator because of a lagged dependent variable and firm fixed effects is likely to be negligible (Phillips and Sul (2007)). The estimation yields $\rho = 0.379$, indicating that idiosyncratic uncertainty does not tend to be long-lastingly persistent.

We identify an uncertainty shock using a Cholesky decomposition with the macro-level uncertainty measure ordered last. This ordering allows us to extract an uncertainty shock by controlling for simultaneous endogeneity, assuming that the uncertainty shock does not have an immediate impact on the seven macroeconomic variables ordered above the uncertainty measure, whereas non-uncertainty shocks can simultaneously affect the uncertainty measure.[12] See Appendix I for the estimated impulse responses to an uncertainty shock in the eight-variable VAR.

Figure 2 shows the three types of estimated exogenous uncertainties. For firm-level exogenous uncertainty, its sample average in each fiscal year is reported.

We use the exogenous uncertainty measures to examine the dynamic effect of uncertainty on corporate investment, particularly focusing on the role of a firm's financing conditions.

4. Empirical Specification and Data In this section, we introduce an empirical specification to examine the role of internal and external financing in corporate investment by firms facing high uncertainty and then discuss the estimation method and our dataset.

4.1. **Measuring the Dynamic Effects of Uncertainty on Corporate Investment** We start by discussing how to measure the dynamic effect of internal and external financing on corporate investment in association with the extent of uncertainty. To this end, along with the framework for identification developed in Section 3.1, we introduce a dynamic investment equation in the following general setting:

$$\begin{aligned} \mathrm{I}_{i,t} &= a_0 \mathrm{I}_{i,t-1} + a_{0u} \mathrm{I}_{i,t-1} \mathrm{U}^s_{i,t-1} + \sum_{k=0}^{m} \left(b_k f_{i,t-k} + b_{ku} f_{i,t-k} \mathrm{U}^s_{i,t-k} \right) + \sum_{k=0}^{m} c_{ku} \mathrm{U}^s_{i,t-k} \\ &\quad + d_0 y_{i,t} + v_t * \mathrm{IND}_i + a_i + \epsilon_{i,t}, \end{aligned} \tag{8}$$

where y_t denotes a variable that controls for the demand conditions for corporate investment such as Tobin's Q (Hoshi and Kashyap (1990), Hayashi and Inoue (1991) and Hennessy et al. (2007)). $v_t * \mathrm{IND}_i$ is the interaction term of the year dummies and industry dummies

[12] Unlike us, Basu and Bundick (2017) order their uncertainty measures first in their VAR. Even if we order the VIXJ and EPUJ first and then use the identified uncertainty shocks in our analysis developed below, it results in qualitatively the same results as those reported in Section 5.

that controls for the time-varying industry effects. a_i is a firm fixed effect that controls for the time-invariant unobservable determinants of firm investment at the firm level. $\varepsilon_{i,t}$ is a stochastic error term.

As discussed above, Bloom (2014) argues that uncertainty affects not only the level of investment, but also the sensitivity of corporate investment to factors that drive investment spending. Regarding the former prediction about the effect of uncertainty, the coefficient parameters c_{ku} capture it as the direct level effect. We focus more on the latter prediction for a particular important relation: the sensitivity of corporate investment to (i) lagged uncertainty shocks and (ii) the internal and external financing variables. In our empirical analysis, the interaction effects a_{0u} and b_{ku} are crucial.

The corporate investment problem is subject to partial irreversibility and fixed adjustment costs (Abel (1983), Bernanke (1983), Abel and Eberly (1994; 1996), Caballero (1999), Cooper and Haltiwanger (2006), Bloom (2007; 2009) and Bachmann et al. (2013a)). These factors create the option value of waiting, meaning that investment expenditure is more likely to be lumpy if it exists. In response to the increase in uncertainty, the region of investment inaction expands; consequently, high uncertainty prevents firms from launching a new investment project and/or maintaining the previous level of lagged investment expenditure, and thus corporate investment and its persistency decrease. Such current and lagged cautionary effects because of increasing uncertainty are encapsulated by the negative estimates of the level effect c_{0u} and sensitivity effect a_{0u}, respectively.

The interaction effect b_{ku} captures how the increase in uncertainty changes the user cost of capital and investment sensitivity to internal and external financing. Recent macroeconomic studies based on DSGE models have pointed out the importance of financial frictions and agency costs as an additional channel through which volatility fluctuations adversely affect macroeconomic outcomes (Brunnermeier and Sannikov (2014), Christiano et al. (2014), and Gilchrist et al. (2014)). According to this literature, to the extent that external financing is subject to agency problems, increasing uncertainty raises the user cost of capital in decreasing the market value of debt claims and then increases the dependence of internal financing such as cash flows and cash reserves. Such an effect of high uncertainty through financial market frictions and a firm's financing constraints is evaluated in terms of whether the interaction effect b_{ku} contributes to increasing investment sensitivity, particularly to internal financing.

In contrast to the theoretical prediction of a positive relation between high uncertainty and investment sensitivity to internal financing, Bloom (2007; 2014), Bloom et al. (2007), and Alfaro et al. (2019) note that uncertainty makes managers less sensitive to changes in fundamental economic and financing conditions such as the cost of capital. According to this notion, the strength of the relation between corporate investment and the cost of capital (i.e., the dependence on internal financing) will be decreasing in uncertainty (see also Drobetz et al. (2018)). The financial aspect of the cautionary effect because of a firm's unresponsiveness to financing conditions and the dominance of this cautionary effect over the above financing constraint effect is assessed in terms of whether the interaction effect b_{ku} contributes to decreasing investment sensitivity to both internal and external financing under high uncertainty.

In the dynamic investment equation (8), the response of corporate investment l period after a change in the financial variable in period t is expressed as in the following marginal effect in period $t+l$ ($l \geq m \geq 0$):

$$\begin{aligned} \mathrm{ME}_{l,f_t}(\mathrm{U}^s_{i,t}) = \frac{\partial \mathrm{I}_{i,t+l}}{\partial f_{i,t}} &= \left(a_0 + a_{0u}\mathrm{U}^s_{i,t}\right) \mathrm{ME}_{l-1,f_t}(\mathrm{U}^s_{i,t}) \\ &= \sum_{l \geq m} \left(a_0 + a_{0u}\mathrm{U}^s_{i,t}\right)^l \left(b_m + b_{mu}\mathrm{U}^s_{i,t}\right). \end{aligned} \tag{9}$$

The cumulative effect through period $t+l$ is defined as $\mathrm{QME}_{0,l,f_t}(\mathrm{U}^s_{i,t}) = \sum_{j=0}^{l} \mathrm{ME}_{j,f_t}(\mathrm{U}^s_{i,t})$, and then the long-run effect for $l \to \infty$ reduces to

$$\mathrm{QME}_{0,\infty,f_t}(\mathrm{U}^s_{i,t}) = \frac{\sum_{k=0}^{m} \left(b_k + b_{ku}\mathrm{U}^s_{i,t}\right)}{1 - a_0 - a_{0u}\mathrm{U}^s_{i,t}}. \tag{10}$$

Equations (9) and (10) show that the marginal and long-run effects depend on the lagged cautionary effect a_{0u} and financial interaction effect b_{ku} as well as the level of uncertainty in the initial period t. Importantly, if the lagged cautionary effect has a negative value, this implies that high uncertainty reduces the dynamic response of corporate investment to a change in the financing variables and promotes a firm's unresponsiveness to financing conditions. If the financial interaction term has a positive (negative) value, it means that the high uncertainty increases (decreases) the dynamic causal link between corporate investment and financing conditions. To examine whether internal and external financing constraints amplify the dynamic effect on corporate investment under high uncertainty, we use the marginal and long-run effects by focusing on both the lagged cautionary effect and the financial interaction effect in our analysis below.

4.2. **Specification for Corporate Investment and Estimation Method** We run the empirical implementation of investment model (8) in the following specification:

$$
\begin{aligned}
\mathrm{I}_{i,t} \;=\;& a_0 \mathrm{I}_{i,t-1} + a_{0u}\mathrm{I}_{i,t-1}\mathrm{U}_{i,t-1} + \sum_{k=0}^{m}\left(b_c^k \mathrm{CF}_{i,t-k} + b_d^k \mathrm{DEBT}_{i,t-k} + b_s^k \mathrm{SI}_{i,t-k}\right) \\
&+ \sum_{k=0}^{m}\left(b_{cu}^k \mathrm{CF}_{i,t-k} + b_{du}^k \mathrm{DEBT}_{i,t-k} + b_{su}^k \mathrm{SI}_{i,t-k}\right) * \mathrm{U}^s_{i,t-k} + \sum_{k=0}^{m} c_{ku}\mathrm{U}^s_{i,t-k} \\
&+ d_q \mathrm{Q}_{i,t} + d_l \mathrm{SALES}_{i,t-1} + v_t * \mathrm{IND}_i + a_i + \epsilon_{i,t}, \qquad (11)
\end{aligned}
$$

where $\mathrm{CF}_{i,t}$ represents the firm's cash flows as a measure of the use of internal financing (Fazzari et al. (1988) and Moyen (2004)). $\mathrm{DEBT}_{i,t}$ and $\mathrm{SI}_{i,t}$ respectively denote the ratio of the firm's debt issues and stock issues to total assets, which are included as measures of the use of external financing (Chen and Chen (2012), Brown and Peterson (2009) and Brown et al. (2009; 2012)). $\mathrm{Q}_{i,t}$ and $\mathrm{SALES}_{i,t-1}$ denote Tobin's Q and the one-lagged value of the sales to total assets ratio that controls for the firm's investment demand.[13]

In firm investment equation (11), we additionally include the interaction terms of the uncertainty indicator with the firm's alternative finance sources—cash flows, debt issues, and stock issues—as well as the interaction term of the uncertainty indicator with the one-period lagged dependent variable. We identify a dynamic relationship between high

[13] The canonical dynamic investment model reduces to an empirical specification for investment that includes the simultaneous value of Tobin's Q as an explanatory variable if its role is investigated (e.g., Hayashi and Inoue (1991)). By contrast, it reduces to a model that includes the one-lagged value of the sales to total assets ratio if its role is focused on (e.g., Bond and Meghir (1994)). Considering this point, we include the simultaneous value of Tobin's Q and the one-lagged value of the sales to total assets ratio in our investment equation, as in Brown et al. (2012).

uncertainty and investment sensitivity to internal and external financing using the financial interaction effects b^k and compare their economic significance with that of the direct cautionary effect a_{0u}, thereby examining how high uncertainty affects investment spending by financially constrained firms.

As discussed in Section 3.1, to estimate the above dynamic panel model with a lagged dependent variable $\mathrm{I}_{i,t-1}$, we employ the Blundell–Bond (1998) system GMM estimation, which allows us to address the potential endogeneity among all the financial variables and interaction terms by estimating firm investment equation (11) in differences and in levels, using lagged levels of the instruments for the regression in differences and lagged differences of the instruments for the regression in levels.

4.3. **Selecting the Lag Length** Before performing a full-fledged analysis of the dynamic effect of uncertainty on corporate investment, we must select lag length m in investment equation (11). To this end, we employ the modified BIC, AIC, and HQIC model selection criteria developed based on Andrews and Lu's (2001) consistent model and moment selection criteria (MMSC) for the GMM estimation: the MMSC-BIC, MMSC-AIC, and MMSC-HQIC (see Appendix II for a detailed definition). In the models using the firm-level uncertainty shock (FIRM), all three MMSC criteria select a zero lag for both capital investment and R&D in a robust manner. As for the two models using the macro-level uncertainty shock, the MMSC-BIC and MMSC-HQIC seem to select a zero lag for both capital investment and R&D, while the MMSC-AIC does not select a particular lag and produces mixed results. As is well known, the BIC and HQIC are more likely to select a shorter lag inherently, whereas the AIC selects a longer lag, although it does not yield a robust result in our empirics. Given this, we adopt the zero lag specification for the firm's capital investment and R&D spending. See Appendix II for the details of the results.

4.4. **Dataset** Table 1 provides the descriptive statistics for each variable. We obtain all the data from the published annual accounts (consolidated base) of manufacturing firms, compiled by Nikkei Digital Media Inc, for our sample period of fiscal years 2001 to 2014. We select manufacturing firms making both capital and R&D investments to compare the dynamics of capital investment and R&D under high uncertainty. For the investment spending ($\mathrm{I}_{i,t}$) included in equation (11), we use the firm's fixed investment or R&D, each defined by dividing the original variables by its total assets, where the fixed investment is defined as the net change in fixed assets plus depreciation.

As for the uncertainty variable ($\mathrm{U}_{i,t}$), we alternately use the exogenous components of the firm-level volatility index $\sigma_{i,t}$ as well as the macro-level uncertainty measures: the VIXJ and EPUJ (see Section 3.2).

As shown in equation (11), we consider three alternative financing sources: cash flows, debt financing, and stock issues. We define cash flows ($\mathrm{CF}_{i,t}$) as the ratio of current net income plus depreciation and amortization to its total assets. For the debt financing of firm i ($\mathrm{DEBT}_{i,t}$), we include the ratio of annual changes in total debt outstanding to its total asset holding. As for the firm's stock issues ($\mathrm{ST}_{i,t}$), we use the amount of stock issues, which is defined as an increase in capital stock when a firm raises both outstanding shares and capital stock, normalized by its total assets.

Tobin's Q ($\mathrm{Q}_{i,t}$) is the ratio of the market value of firm i to its book value, where the market value of the firm is the market value of its equity plus the book value of its total liabilities.[14] Sales ($\mathrm{SALES}_{i,t}$) is defined as the ratio of the firm's gross sales to its total assets. We include the two firm covariates to control for the firm's investment demand. The industry dummy variables are set according to the 17 industry sectors defined by the Securities Identification Code Committee in Japan.

5. Estimation Results In this section, we report the estimation results for corporate investment equation (11), particularly focusing on the effect of uncertainty on the sensitivity of corporate investment spending to internal and external financing. By doing so, we examine how firms finance capital investment and R&D under high uncertainty and then analyze the differences that exist between these two types of investment spending.

5.1. **Uncertainty and Capital Investment** Table 2 reports the estimation results for capital investment spending. The left, middle, and right panels of this table show the results obtained using the firm-level volatility shock (FIRM), macro-level volatility shock

[14] We calculate the market value of equity by multiplying the end-of-year stock price by the number of shares.

based on the VIXJ, and economic policy uncertainty shock based on the EPUJ (see Section 3.2), respectively. The columns in each panel report the zero- or one-lag models with or without the interaction terms with the uncertainty shocks. Here, we emphasize the zero-lag model since the information criteria select a zero lag for most specifications of capital investment spending, as discussed in Section 4.2. To ensure that the results do not rely on the lag length, we show the estimation results of the one-lag model including the firm-level volatility shock as an uncertainty shock.

The coefficients on the lagged dependent variable of capital investment a_0 are significantly estimated to be around 0.16 to 0.18, indicating that the shortage of internal and external financing sources has a short-lasting effect on capital investment. More importantly, the lagged cautionary effect a_{0u} has significantly negative values aside from the EPUJ, which implies that high uncertainty reduces the persistence of capital investment and that capital investment becomes more lumpy because firms are reluctant to maintain the previous level of capital investment under high uncertainty.

Internal financing sources b_k appear to have significantly positive estimates for cash flows in a statistically robust manner. As for external financing sources, debt issuances have positive estimates. This finding implies that as long as uncertainty is lower, firms are more likely to increase capital investment by raising cash flows and/or issuing debt.

The financial interaction effects with the three financing variables b_{ku} in the models using the firm-level uncertainty shock appear to have significantly negative estimates for cash flows. The interaction effects with external financing sources also have a negative sign, although they are not statistically significant. This finding implies that high uncertainty reduces the sensitivity of capital investment to cash flows because of the cautionary channel (Bloom (2007), Bloom et al. (2007) and Alfaro et al. (2019)), through which a firm's unresponsiveness to financing conditions is more pronounced under high uncertainty.

Such a cautionary channel can be observed in terms of the dynamic response of capital investment. Figure 3 reports the estimated dynamic responses of capital investment to a 1% change in the three financing variables at low and high levels of firm-level uncertainty obtained using the zero-lag model. Apparently, high uncertainty amplifies the dynamic response of capital investment to a shock to cash flows to a lesser degree.

Under low uncertainty, the dynamic response to cash flows has a significantly positive value for a longer period than under high uncertainty. This finding implies that at low uncertainty, firms finance capital investment using cash flows; however, under high uncertainty, the cautionary effect weakens this causal link between capital investment and internal financing. The previous literature points out that high uncertainty raises the cost of capital and worsens financing conditions (Merton (1974), Bernanke and Gilchrist (1996), Kiyotaki and Moore (1997), Brunnermeier and Sannikov (2014), Christiano et al. (2014) and Gilchrist et al. (2014)); however, firms respond less to such deteriorated financing conditions under the cautionary strategy when making capital investment decisions under high uncertainty (Bloom (2007; 2014), Bloom et al. (2007), Drobetz et al. (2018) and Alfaro et al. (2019)).

The dynamic response to debt issues has a significantly positive value under low uncertainty, whereas the response under high uncertainty is not statistically significant. High uncertainty lessens the sensitivity of not only cash flows but also debt insurance on capital investment, and thus we show that the sensitivity of financing to capital investment weakens under uncertainty because of the cautionary effect of uncertainty.

Further, the investment equations that do not control for the interaction effects with uncertainty shocks have significantly negative estimates for their level effect c_{0u}, or the simultaneous cautionary effect, indicating that increasing uncertainty directly and simultaneously decreases capital investment. However, once the investment equations also control for the sensitivity effects with uncertainty a_{0u} and b_{ku}, such a level effect vanishes. Given these results, the sensitivity effect through the investment latency structure and the firm's financing conditions would have a more substantive role in capital investment than the direct level effect.

5.2. **Uncertainty and R&D** Next, we report the estimation results for R&D. Table 3 reports the zero-lag models with or without the interaction terms with uncertainty and the one-lag model with the interaction terms. We again focus on the zero-lag model because the information criteria selected a zero lag for most of the specifications of R&D investment, as discussed in Section 4.3.

The most noticeable difference between R&D and capital investment is that the estimated coefficients on the lagged dependent variable of R&D a_0 are much higher than those on the lagged dependent variable of capital investment, being close to one. This finding implies that compared with capital investment, R&D has a more persistent feature and fairly near random work behavior; put differently, a one-time shock to R&D has a permanent effect without it disappearing intertemporally. Moreover, the lagged cautionary effect a_{0u} in R&D has a not statistically significant and lower negative value than that in capital investment does, which indicates that even if firms face fluctuations in uncertainty, they are more likely to maintain the level of R&D and engage in R&D smoothing (Brown et al. (2009; 2012) and Hall et al. (2016)).

Considering that the estimated coefficients on the lagged dependent variable are close to one, we test whether they are statistically indistinguishable from one, $a_0 = 1$. If the coefficient on the lagged dependent variable is close to one, the weak instrument problem can emerge—even when employing the Blundell–Bond (1998) system GMM estimation (see Section 3.1). As shown in the bottom row of Table 3, the hypothesis $a_0 = 1$ is rejected in a statistically significant manner in the zero-lag model, whereas the hypothesis in the one-lag model is not rejected. Since the tests for lag selection support the zero-lag model, the concern on $a_0 = 1$ is inconsiderable; nonetheless, to ensure the validity of our results, we also estimate the R&D equation with the restriction $a_0 = 1$ using the same instruments. Table 4 reports the estimation results for the models using the difference in R&D (ΔR&D) as the dependent variable, showing qualitatively the same results as in Table 3.

Tables 3 and 4 also share the quality of the estimation results for the financing variables b_k and their interaction effects with uncertainty b_{ku} in that the interaction effect with internal financing sources in R&D investment is much weaker than that in capital investment in terms not only of magnitude, but also of quality: only cash flows have significantly positive estimates in a qualitatively robust manner.

Figure 4 shows the estimated dynamic responses of R&D to a 1% change in the three financing variables at low and high levels of firm-level uncertainty obtained using the zero-lag model of Table 3. Except for R&D–cash flow sensitivity, sensitivity to debt as well as stock issuances is not significant. From the dynamics in R&D–cash flow sensitivity, we observe that under low uncertainty, R&D is much more persistently affected following a financial shock to cash flows than capital investment is, although the estimated impact on R&D is much smaller than that on capital investment. However, most importantly, as in capital investment, high uncertainty also weakens the causal link between R&D and cash flows. That is, although R&D is longer-lasting than capital investment, but less negatively affected by the shortage of cash flows (i.e., external funding constraints) under high uncertainty, these two types of corporate investments share evidence that high uncertainty amplifies the dynamic response to a shock to the internal financing source because of the cautionary effect to a lesser extent.

5.3. **Uncertainty and the Long-run Effect** Table 5 shows the long-run effect of a financing shock on corporate investment and R&D using the firm-level uncertainty shock (see equation (10) in Section 4.1 for the long-run effect). As shown in panel (a) for capital investment, the long-run effect of an internal financing shock to cash flows is much smaller under high uncertainty than under low uncertainty, indicating that as uncertainty increases, the importance of internal financing (i.e., financing constraints) becomes smaller in making capital investment decisions. Furthermore, a debt issuance shock has less effect on capital investment under high uncertainty, although the difference between low and high uncertainty is slightly smaller than that for internal financing. Further, a stock issuance shock does not yield significant long-run effects under low or high uncertainty.

Compared with capital investment, the long-run effect of each financing shock shown in panel (b) for R&D investment is very weak in terms of its significance; however, the magnitude of the long-run effect to a cash flow shock for R&D spending is larger than that for capital investment spending under both low and high uncertainty. In the previous subsection, we found that under low uncertainty, R&D is much more persistently affected following a cash flow shock than capital investment is, although the temporal impact on R&D is much smaller than that on capital investment. Given this finding, the larger long-run effect of a financial shock to cash flows on R&D could be attributed to its inherent long-lasting persistency. Nonetheless, given that the point estimates of the long-run effect of a cash flow shock on R&D appear to be much smaller under high uncertainty than under low uncertainty, R&D also shares with capital investment evidence that as uncertainty increases, the importance of internal financing (i.e., a firm's financing constraints) becomes smaller when making both types of corporate investments because of the cautionary effect.

Summing up our dynamic analysis, a financial shock to internal financing sources (i.e., cash flows) has a more short-lasting, but larger impact on capital investment, whereas it has a longer-lasting, but smaller temporal impact on R&D. However, this internal financing shock has a larger long-run impact on R&D investment because of its inherent long-lasting persistency based on the higher adjustment costs of the intangibles accumulated through R&D investment, as pointed out by Williamson (1988) and Bloom and Van Reenen (2002).

5.4. **Weak Instrument Robust Inference for the Cautionary Effect** The plausibility of our empirical results presented thus far relies on the assumption that our instruments in the system GMM estimation are relevant to the three financing variables and their interaction terms with the uncertainty shocks. However, unacknowledged weak instruments could provide us with a spurious finding because no standard test for weak instruments in dynamic panel GMM regressions exists (see Bazzi and Clemens (2013)). To address this potential problem, we employ the Kleibergen (2005) testing procedure to conduct the weak instrument robust inference. The Kleibergen procedure has better power properties than the conventional Anderson and Rubin procedure in many instruments. This procedure thus allows us to generate joint confidence sets for the case of multiple endogenous variables based on the null hypothesis that a coefficient parameter on an endogenous variable takes the true value and the instruments are valid (Kleibergen (2005) refers this test as the J-K test); therefore, the confidence set derived using the J-K test is robust not only to weak instruments, but also to invalid instruments.

When employing the Kleibergen procedure, we conduct the weak instrument robust inference for two estimated coefficients on cash flows and its interaction term with the firm-level uncertainty shock. This is because the two coefficients mainly involve our finding that high uncertainty reduces the sensitivity of capital investment and R&D to this internal financing source because of the cautionary channel. Figure 5 shows the joint confidence sets for the two estimated coefficients in the models of capital investment (panel (a)) and R&D (panel (b)), both of which are based on the non-lagged models in equation (11) (see

Section 4.3 for the lag selection).[15] WALD and J-K denote the 90% joint confidence sets derived using the conventional Wald test and J-K test, respectively.

Regarding capital investment, the joint confidence set of the estimated coefficients on cash flow (horizontal line) and its interaction term with the firm-level uncertainty shock (vertical line) appears not to depend on the Wald and J-K tests. The interaction effect between cash flow and uncertainty falls into a negative region, even in the J-K test, indicating that the finding that high uncertainty decreases capital investment–cash flow sensitivity is robust not only to weak instruments, but also to invalid instruments.

As for R&D investment, the joint confidence set derived using the J-K test appears to be different from that derived using the Wald test; more concretely, the J-K 90% confidence interval of the interaction effect between cash flow and uncertainty takes a significantly larger negative region than the Wald one. This finding indicates that only the system GMM regression would lead to the underestimation of the interaction effect with uncertainty, unless the weak instrument robust inference is not conducted.

Our weak instrument robust inference based on the Kleibergen (2005) procedure strongly suggests that our key result—high uncertainty reduces the cash flow sensitivity of capital investment and R&D—holds in a statistically robust manner, even if our instruments are weak and invalid.

5.5. **Cash Holdings and Investment–Cash Flow Sensitivity** Some previous literature has focused on the role of firms' cash holdings as their precautionary motive for financing future corporate investment (Almeida et al. (2014)). Here, we address the issue of whether or how investment–cash flow sensitivity depends on firms' cash holdings under uncertainty. To this end, we define cash-rich firms as an indicator variable of firms with higher cash holdings. Then, we include the interaction term of cash flows ($\mathrm{CF}_{i,t}$) and the indicator of cash-rich firms as well as the triple interaction term of cash flows, the uncertainty variable ($\mathrm{U}_{i,t}$), and the indicator of cash-rich firms into capital investment equation (11).

Table 6 shows the estimation results for capital investment equation (11) including the

[15] We confirm that the one-lag models for capital and R&D investment produce the qualitatively same results reported below.

two interaction terms. In this table, we define two types of indicators of cash-rich firms in the top 50th and 70th percentiles of cash holdings to total assets. The interaction terms of cash flows ($\mathrm{CF}_{i,t}$) and indicator of cash-rich firms appear to have significantly negative coefficients, implying that investment–cash flow sensitivity decreases (increases) for cash-rich (cash-poor) firms. The triple interaction terms appear to cancel the interaction effect of cash flows and the uncertainty variable: in other words, cash-rich firms do not suffer from the cautionary effect caused by uncertainty shocks.

We can observe these estimation results more clearly in Figure 6, which shows the dynamic response of capital investment to a one-unit change in cash flows for cash-rich (upper panels) and cash-poor firms (lower panels) under low (left panels) and high uncertainty (right panels) for firms in the top 50th percentiles of cash holdings. This figure shows that investment–cash flow sensitivity for cash-rich firms diminishes in the cases of both low and high uncertainty. However, investment–cash flow sensitivity for cash-poor firms still remains high and low under low and high uncertainty, respectively. Our results thus far indicate that the cautionary effect would emerge for firms with less cash holdings—even though this effect becomes more substantial under high uncertainty—-but not for firms with more cash holdings.

5.6. **Shortage of Internal Financing and Corporate Investment Under High Uncertainty** The above analysis provides an important insight into the causal link between the shortage of internal financing and corporate investment under high uncertainty. The shortage of internal financing under high uncertainty has different effects on capital investment and R&D in terms of persistency, but the same effects in terms of quality. If firms lack sufficient access to internal financing—cash flows and cash holdings—under high uncertainty, such a liquidity shortage has a negative effect on both capital investment and R&D; however, this liquidity shortage is longer-lasting for R&D than for capital investment.

Although the persistence of the liquidity shortage effect under high uncertainty is different between capital investment and R&D, the two types of investments share the effect of uncertainty through which investment sensitivity to internal financing sources (i.e., the firm's external financing constraints) decreases in uncertainty because of cautionary behavior. Such a financial aspect of the cautionary effect is particularly remarkable in capital investment in terms of its magnitude, making the firm's financing conditions indifferent to their investment decisions and thus reducing the level of capital investment over time because of the directly negative effect of uncertainty.

Given that R&D investment inherently has a high degree of intertemporal inertia because of higher adjustment costs (Williamson (1988) and Bloom and Van Reenen (2002)), it is reasonable that for R&D investment, not only the directly negative effect of uncertainty, but also the firm's unresponsiveness to financing conditions because of cautionary behavior is much weaker even under high uncertainty than for capital investment; however, once firms face a shortage of internal financing, such a shortage has a larger long-run impact on R&D because of its inherent intertemporal inertia.

Nonetheless, irrespective of those differences, most importantly, capital investment and R&D share the cautionary effect through which the firm's internal and external financing conditions become indifferent to actual corporate investment decisions under high uncertainty.

6. Conclusion High uncertainty has two channels through which the relation between corporate investment and financing conditions is affected. The first channel involves financing constraints: firms with a higher cost of capital depend more on internal financing and their investment sensitivity to internal financing increases. The second channel is based on a financial aspect of cautionary behavior through which the strength of investment–internal financing sensitivity is decreasing in uncertainty because of the firm's unresponsiveness to the financing conditions.

Using firm-level data on the Japanese manufacturing industry from fiscal years 2001 to 2014, this study identifies the causal effect of uncertainty on the dynamic relation between corporate investment and financing conditions, thus demonstrating that the cautionary effect is increasingly dominant under high uncertainty irrespective of the type of corporate investment: capital investment and R&D. The dominance of the cautionary effect over the financing constraint effect makes the firm's financing conditions under high uncertainty indifferent to actual corporate investment decisions, thereby reducing corporate investment gradually over time.

To establish this main finding, we first demonstrated that under high uncertainty, capital investment and R&D are differently affected by a shortage of internal financing in terms of magnitude and persistency; however, they share the cautionary effect in terms of quality. In terms of magnitude and persistency, the more severe availability of internal financing—cash flows and cash holdings—has a more short-lasting, but a temporarily larger impact on capital investment, whereas it has a longer-lasting, but temporarily smaller impact on R&D. These severe internal financing constraints under high uncertainty result in a larger long-run impact on R&D because of its inherent long-lasting persistency based on the higher adjustment costs of the intangibles accumulated through R&D investment (Williamson (1988) and Bloom and Van Reenen (2002)).

Nonetheless, irrespective of those differences, most importantly, we found that capital investment and R&D share the cautionary effect through which the firm's internal and external financing conditions become indifferent to actual corporate investment decisions under high uncertainty. We established this evidence in a statistically rigorous manner in terms of dynamic causal inference, not only by first setting up a quasi-natural experiment with a randomized shock of uncertainty and next employing the instrumental variable estimation approach, but also by accounting for the weakness and validity of our instruments. Effective policy options for stagnant corporate investment heavily depend on whether it is because of an increase in financial frictions or firms' cautionary strategy. Our evidence suggests that policies aimed at easing firms' financing constraints cannot work without lowering the uncertainty they face.

Appendix I: Impulse Responses to an Uncertainty Shock We estimate a structural VAR to identify an uncertainty shock as a purely exogenous movement in the two uncertainty indicators: the VIXJ and EPUJ. Following Basu and Bundick (2017), we estimate a VAR with the following eight variables: one of the uncertainty indicators, GDP, consumption, investment, a GDP deflater, stock price (Nikkei 225 index), and two indicators of the monetary policy stance: the monetary base and short-term policy rate (overnight call rate). Since the VIXJ and EPUJ data start in 1998 and 1988, respectively, we estimate the VAR using quarterly data over the 1998 and 2015 sample periods. With the exception of the uncertainty indicators and short-term policy rate, all the other variables enter the VAR in log levels. We identify an uncertainty shock using a Cholesky decomposition with the VIXJ and EPUJ ordered last.

Here, we only report the estimated impulse responses to an identified uncertainty shock of the VIXJ because the two uncertainty shocks of the VIXJ and EPUJ produce qualitatively similar impulse responses. Figure A plots the estimated impulse responses to a one-standard-deviation uncertainty shock along with the 90% confidence intervals. The one-standard-deviation shock increases the VIXJ by 3%. Following the shock, output, consumption, investment, and stock prices all decline together, with their peak responses occurring after about one year. The peak decline in investment is roughly five times as large as the decline in output and consumption. Prices begin to decrease about two year after the uncertainty shock hits and then continue to fall. The declines in economic activity and inflation lead the monetary authority to reduce its nominal interest rate and increase the monetary base, although such a response is not immediate and statistically indistinguishable from zero, particularly for the monetary base. The above results are qualitatively similar to the findings of previous studies of the economy's response to an uncertainty shock, including Christiano et al. (2014), Gilchrist et al. (2014), Jurado et al. (2015), and Basu and Bundick (2017).

Appendix II: Lag Selection in the Dynamic Investment Model To select the lag length in dynamic investment model (1), we employ Andrews and Lu's (2001) consistent MMSC for the GMM estimation. They define the conventional BIC, AIC, and HQIC model selection criteria in the framework of the MMSC as follows:

$$\text{MMSC-BIC}_n(b,c) = J_n(b,c) - (|c| - |b|)\ln n, \tag{A-1}$$

$$\text{MMSC-AIC}_n(b,c) = J_n(b,c) - 2(|\mathrm{c}| - |\mathrm{b}|), \tag{A-2}$$

$$\text{MMSC-HQIC}_n(b,c) = J_n(b,c) - Q(|c| - |b|)\ln\ln n, \tag{A-3}$$

where n is the number of observations and $|b|$ and $|c|$ denote the number of parameters b and moments c in the GMM estimation, respectively. $J_n(b,c)$ indicates the J test statistics for testing overidentifying restrictions, constructed based on the parameters b and moments c. Q is a parameter that meets $Q > 2$.

When selecting lag length m in corporate investment equation (11), we calculate the three types of MMSC criteria for the one- to three-lag models and then select a model that minimizes each of these criteria. When calculating the MMSC-HQIC, we set the parameter Q to $Q = 2.1$. Table A reports the calculated information criteria for each lag model. In the models using the firm-level uncertainty shock (FIRM), all three MMSC criteria select a zero lag for both capital investment and R&D in a robust manner. As for the two models using the macro-level uncertainty shock, the MMSC-BIC and MMSC-HQIC seem to select a zero lag for both capital investment and R&D, while the MMSC-AIC does not select a particular lag and produces mixed results. As is well known, the BIC and HQIC are more likely to select a shorter lag inherently, whereas the AIC selects a longer lag, although it does not yield a robust result in our empirics. Given this, we adopt the zero-lag specification for the firm's capital investment and R&D spending.

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Table 1: **Descriptive Statistics**

year	R&D	Capital Invest.	Cash Flow	Debt Issue	Stock Issue	Sales	Tobin's Q
2001	0.023	0.040	0.046	0.018	0.002	0.924	0.987
	(0.02)	(0.035)	(0.046)	(0.077)	(0.009)	(0.3)	(0.311)
2002	0.023	0.038	0.037	-0.036	0.001	0.853	0.936
	(0.02)	(0.035)	(0.041)	(0.062)	(0.004)	(0.303)	(0.29)
2003	0.024	0.028	0.044	-0.021	0.001	0.890	0.898
	(0.021)	(0.03)	(0.045)	(0.068)	(0.005)	(0.313)	(0.263)
2004	0.025	0.029	0.057	-0.003	0.001	0.946	1.056
	(0.022)	(0.032)	(0.04)	(0.064)	(0.008)	(0.324)	(0.315)
2005	0.025	0.037	0.065	0.002	0.002	0.979	1.105
	(0.022)	(0.035)	(0.042)	(0.068)	(0.008)	(0.324)	(0.292)
2006	0.025	0.041	0.064	0.015	0.002	1.000	1.240
	(0.022)	(0.04)	(0.046)	(0.068)	(0.01)	(0.322)	(0.374)
2007	0.024	0.044	0.067	0.019	0.002	1.007	1.142
	(0.022)	(0.037)	(0.045)	(0.071)	(0.01)	(0.322)	(0.344)
2008	0.024	0.041	0.064	-0.013	0.001	1.000	0.953
	(0.022)	(0.033)	(0.05)	(0.067)	(0.006)	(0.318)	(0.277)
2009	0.024	0.031	0.032	-0.037	0.000	0.907	0.849
	(0.021)	(0.032)	(0.056)	(0.074)	(0.004)	(0.314)	(0.25)
2010	0.024	0.029	0.051	-0.002	0.001	0.886	0.948
	(0.022)	(0.029)	(0.053)	(0.071)	(0.007)	(0.327)	(0.299)
2011	0.024	0.030	0.065	0.002	0.001	0.940	0.917
	(0.021)	(0.03)	(0.046)	(0.07)	(0.005)	(0.308)	(0.263)
2012	0.024	0.037	0.062	0.010	0.001	0.945	0.903
	(0.022)	(0.033)	(0.046)	(0.069)	(0.005)	(0.315)	(0.256)
2013	0.024	0.046	0.062	0.005	0.001	0.931	0.936
	(0.021)	(0.038)	(0.045)	(0.067)	(0.005)	(0.311)	(0.307)
2014	0.024	0.048	0.071	0.024	0.001	0.968	0.982
	(0.021)	(0.037)	(0.041)	(0.061)	(0.006)	(0.318)	(0.331)
Total	0.024	0.037	0.056	-0.001	0.001	0.942	0.989
	(0.021)	(0.035)	(0.048)	(0.071)	(0.007)	(0.319)	(0.317)

Note: The sample period is fiscal years 2001 to 2014, although we estimate the models from 2004 to 2014 because we use two- and three-lagged variables as instruments. The values in the rows and parentheses respectively report the sample average and standard deviation for each year and total observations. All the variables except for Tobin's Q are scaled by total assets at the beginning of the period. We preliminarily remove the outliers (i.e., those values three standard deviations away from the mean).

Table 2: **Estimation Results for the Capital Investment Equation using System GMM**

Uncertainty Shock:	FIRM	FIRM	FIRM	VIXJ	VIXJ	EPUJ	EPUJ
N of Lag:	0 Lag	0 Lag	1 Lag	0 Lag	0 Lag	0 Lag	0 Lag
Parameters: a_0 **and** a_{0u}							
INV_{t-1}	0.169***	0.159***	0.179***	0.175***	0.176***	0.174***	0.181***
	(0.021)	(0.020)	(0.020)	(0.018)	(0.018)	(0.019)	(0.018)
INV_{t-1}*U_{t-1}		-0.138***	-0.251***		-7.070***		0.275
		(0.040)	(0.055)		(1.358)		(0.202)
Parameters: b_k $(k = 0, 1)$							
CASHFLOW_t	0.103***	0.120*	0.267***	0.100***	0.096***	0.098***	0.138***
	(0.030)	(0.063)	(0.057)	(0.035)	(0.022)	(0.032)	(0.030)
DEBT_t	0.130***	0.145***	0.128***	0.122***	0.124***	0.124***	0.104***
	(0.033)	(0.036)	(0.040)	(0.028)	(0.035)	(0.030)	(0.035)
STOCKISSUE_t	0.073	-0.036	-0.139	-0.020	0.251	0.001	0.167
	(0.324)	(0.304)	(0.295)	(0.284)	(0.423)	(0.295)	(0.228)
CASHFLOW_{t-1}			-0.222				
			(0.200)				
DEBT_{t-1}			-0.142				
			(0.158)				
STOCKISSUE_{t-1}			-0.391				
			(0.818)				
Parameters: b_{ku} $(k = 0, 1)$							
CASHFLOW_t*U_t		-0.302*	-0.060***		2.191		2.715***
		(0.169)	(0.021)		(2.596)		(0.704)
DEBT_t*U_t		-0.229	-0.011*		-0.183		-1.145
		(0.178)	(0.006)		(4.221)		(0.935)
STOCKISSUE_t*U_t		-0.536	-0.023		98.804		-11.014*
		(1.197)	(0.061)		(61.304)		(6.422)
CASHFLOW_{t-1}*U_{t-1}			0.017				
			(0.042)				
DEBT_{t-1}*U_{t-1}			0.009				
			(0.024)				
STOCKISSUE_{t-1}*U_{t-1}			0.205				
			(0.236)				
Parameters: c_{ku} $(k = 0, 1)$							
U_t	-0.005**	0.012	0.008	0.026	-0.314*	-0.013	-0.120**
	(0.002)	(0.009)	(0.011)	(0.072)	(0.179)	(0.014)	(0.047)
U_{t-1}			0.005*				
			(0.003)				
TOBINQ_t	0.012*	0.005	-0.001	0.016***	0.009	0.015***	0.002
	(0.006)	(0.008)	(0.008)	(0.005)	(0.006)	(0.006)	(0.006)
SALES_{t-1}	0.024***	0.026***	0.027***	0.023***	0.026***	0.024***	0.022***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)
Constant	-0.013**	-0.008	-0.009	-0.016***	-0.012*	-0.015**	-0.005
	(0.006)	(0.007)	(0.008)	(0.005)	(0.007)	(0.006)	(0.008)
Dummy variable	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.
N	12303	12303	12303	12303	12303	12303	12303
N of IVs	371	383	385	371	383	371	383
Hansen test (p-value)	0.198	0.259	0.485	0.337	0.332	0.302	0.477
Arellano-Bond test for AR(1). p-value	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Arellano-Bond test for AR(2). p-value	0.061	0.485	0.767	.	0.498	.	0.214

Note: The dynamic capital investment models from equation (11) are estimated using the Blundell–Bond system GMM. The dependent variable is capital investment divided by total assets (INV). We use three types of uncertainty shocks (U): the firm-level uncertainty shock (FIRM) and two macro-level uncertainty shocks extracted from the VIXJ and EPUJ. Year×Ind. indicates the cross-terms of the time dummy and industrial dummy variables. The uncertainty shock, Year×Ind. and two- and three-lagged values of all the explanatory variables are used as instrumental variables. Standard errors are in parentheses. *, **, and *** represent the 10%, 5%, and 1% levels of significance, respectively.

Table 3: **Estimation Results for the R&D Equation using System GMM**

Uncertainty Shock:	FIRM	FIRM	FIRM	VIXJ	VIXJ	EPUJ	EPUJ
N of Lag:	0 Lag	0 Lag	1 Lag	0 Lag	0 Lag	0 Lag	0 Lag
Parameters: a_0 **and** a_{0u}							
R&D$_{t-1}$	0.969***	0.959***	0.986***	0.971***	0.949***	0.967***	0.949***
	(0.019)	(0.018)	(0.013)	(0.018)	(0.021)	(0.019)	(0.021)
R&D$_{t-1}$*U$_{t-1}$		-0.020	-0.006		-0.320		0.087
		(0.019)	(0.020)		(0.510)		(0.136)
Parameters: b_k $(k = 0, 1)$							
CASHFLOW$_t$	0.021**	0.024***	0.020**	0.022**	0.022***	0.022***	0.025***
	(0.008)	(0.009)	(0.010)	(0.009)	(0.006)	(0.008)	(0.008)
DEBT$_t$	-0.006	-0.007	0.004	-0.006	-0.011*	-0.008	-0.017**
	(0.008)	(0.008)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)
STOCKISSUE$_t$	0.170*	0.091	0.068	0.155*	0.130	0.153	0.179**
	(0.098)	(0.080)	(0.086)	(0.088)	(0.091)	(0.097)	(0.085)
CASHFLOW$_{t-1}$			-0.006				
			(0.005)				
DEBT$_{t-1}$			-0.016***				
			(0.001)				
STOCKISSUE$_{t-1}$			-0.014				
			(0.014)				
Parameters: b_{ku} $(k = 0, 1)$							
CASHFLOW$_t$*U$_t$		-0.055	0.012		1.281**		0.530*
		(0.039)	(0.033)		(0.555)		(0.284)
DEBT$_t$*U$_t$		-0.017	-0.044		-0.345		-0.316
		(0.035)	(0.028)		(0.683)		(0.310)
STOCKISSUE$_t$*U$_t$		0.349	0.237		31.988**		3.098
		(0.293)	(0.249)		(15.741)		(2.270)
CASHFLOW$_{t-1}$*U$_{t-1}$			0.006				
			(0.007)				
DEBT$_{t-1}$*U$_{t-1}$			0.004				
			(0.005)				
STOCKISSUE$_{t-1}$*U$_{t-1}$			-0.004				
			(0.041)				
Parameters: c_{ku} $(k = 0, 1)$							
U$_t$	-0.000	0.002	-0.001	0.029	-0.102***	-0.001	-0.042**
	(0.000)	(0.002)	(0.002)	(0.022)	(0.040)	(0.003)	(0.018)
U$_{t-1}$			-0.000				
			(0.001)				
TOBINQ$_t$	-0.001	-0.000	0.001	-0.001	0.000	-0.001	-0.000
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SALES$_{t-1}$	-0.004***	-0.004***	-0.000	-0.004***	-0.003***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.005***	0.004**	-0.001	0.005***	0.003**	0.005***	0.005***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
Dummy variable	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.	Year×Ind.
N	11202	11202	11202	11202	11202	11202	11202
N of IVs	345	361	363	345	361	345	361
Hansen test (p-value)	0.912	0.967	0.999	0.938	0.997	0.887	0.997
Arellano-Bond test for AR(1). p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arellano-Bond test for AR(2). p-value	0.141	0.889	0.972	0.015	0.104	0.288	0.473
Test for b(R&D$_{t-1}$) = 1 (p-value)	0.093	0.026	0.268	0.112	0.014	0.078	0.016

Note: The dynamic R&D investment models from equation (11) are estimated using the Blundell–Bond system GMM. The dependent variable is R&D divided by total assets. The uncertainty shock, Year×Ind., and two- and three-lagged values of all the explanatory variables are used as instrumental variables. See also the note of Table 2.

Table 4: **Estimation Results for Differenced R&D Spending using System GMM**

Dependent Variable:	Differenced R&D Spending	
Uncertainty Shock:	Firm-level Shock	
N of Lag:	0 Lag	1 Lag
Parameter: a_{0u}		
R&D$_{t-1}$*U$_{t-1}$	-0.015	-0.022
	(0.019)	(0.020)
Parameters: b_k $(k = 0, 1)$		
CASHFLOW$_t$	0.025***	0.007
	(0.009)	(0.006)
DEBT$_t$	-0.009	0.006
	(0.007)	(0.004)
STOCKISSUE$_t$	0.091	0.018
	(0.077)	(0.079)
CASHFLOW$_{t-1}$		-0.005
		(0.005)
DEBT$_{t-1}$		-0.017***
		(0.001)
STOCKISSUE$_{t-1}$		-0.012
		(0.013)
Parameters: b_{ku} $(k = 0, 1)$		
CASHFLOW$_t$*U$_t$	-0.063	-0.003
	(0.044)	(0.032)
DEBT$_t$*U$_t$	-0.016	-0.013
	(0.038)	(0.022)
STOCKISSUE$_t$*U$_t$	0.377	0.135
	(0.309)	(0.262)
CASHFLOW$_{t-1}$*U$_{t-1}$		0.005
		(0.007)
DEBT$_{t-1}$*U$_{t-1}$		0.000
		(0.004)
STOCKISSUE$_{t-1}$*U$_{t-1}$		-0.008
		(0.032)
Parameters: c_{ku} $(k = 0, 1)$		
U$_t$	0.003	-0.000
	(0.002)	(0.002)
U$_{t-1}$		-0.000
		(0.002)
TOBINQ$_t$	-0.001	0.003*
	(0.002)	(0.001)
SALES$_{t-1}$	-0.004***	0.001
	(0.001)	(0.000)
Constant	0.004**	-0.003**
	(0.002)	(0.001)
Dummy variable	Year×Ind.	Year×Ind.
N	11202	11202
N of IVs	357	359
Hansen test (p-value)	0.986	0.998
Arellano-Bond test for AR(1). p-value	0.000	0.000
Arellano-Bond test for AR(2). p-value	0.459	0.270

Note: The dynamic R&D investment models from equation (11) with the restriction $a_0 = 1$ are estimated using the Blundell–Bond system GMM. The dependent variable is the differenced values of R&D divided by total assets. We use the same instrumental variables as described in the note of Table 2.

Table 5: **Long-run Effects of Marginal Changes in the Financing Variables**

(a) Capital Investment

	Zero-lag Model	
	Lower Uncertainty	Higher Uncertainty
CASHFLOW	0.271**	0.029
	(0.125)	(0.071)
DEBT	0.274***	0.083
	(0.08)	(0.078)
STOCKISSUE	0.170	-0.230
	(0.546)	(0.600)

(b) R&D Investment

	Zero-lag Model	
	Lower Uncertainty	Higher Uncertainty
CASHFLOW	1.203	0.142
	(0.752)	(0.288)
DEBT	-0.046	-0.264
	(0.370)	(0.325)
STOCKISSUE	-0.596	4.268
	(1.882)	(3.967)

Note: We measure the long-run effects of marginal changes in the financing variables on capital investment and R&D investment, as represented in equation (10), using the parameter estimates of the zero-lag models in Tables 2 and 3. The 10th percentile value of the firm-level uncertainty shock is defined as the low uncertainty shock, while the 90th percentile value is defined as the high uncertainty shock. Standard errors are in parentheses. *, **, and *** represent the 10%, 5%, and 1% levels of significance, respectively.

Table 6: **Estimation Results for the Capital Investment Equation using System GMM: Effect of Cash Holdings**

Uncertainty Shock:	FIRM	FIRM
CASHRICH:	50 percentiles	70 percentiles
Parameters: a_0 **and** a_{0u}		
INV_{t-1}	0.173***	0.174***
	(0.021)	(0.019)
$\text{INV}_{t-1}*\text{U}_{t-1}$	-0.162***	-0.133***
	(0.040)	(0.033)
Parameters: b_0		
CASHFLOW_t	0.277***	0.267***
	(0.057)	(0.051)
$\text{CASHFLOW}_t*\text{CASHRICH}_t$	-0.233***	-0.199***
	(0.068)	(0.054)
DEBT_t	0.114***	0.114***
	(0.047)	(0.038)
STOCKISSUE_t	-0.100	0.049
	(0.263)	(0.275)
Parameters: b_{0u}		
$\text{CASHFLOW}_t*\text{U}_t$	-0.334	-0.389*
	(0.234)	(0.204)
$\text{CASHFLOW}_t*\text{U}_t*\text{CASHRICH}_t$	0.424***	0.365*
	(0.213)	(0.188)
DEBT_t*U_t	-0.170	-0.226*
	(0.141)	(0.137)
$\text{STOCKISSUE}_t*\text{U}_t$	-0.514	-0.228
	(0.640)	(0.907)
Parameters: c_{0u}		
U_t	0.000	0.009
	(0.010)	(0.010)
TOBINQ_t	0.009	0.004
	(0.007)	(0.006)
SALES_{t-1}	0.026***	0.021***
	(0.007)	(0.006)
Constant	-0.015*	-0.009
	(0.008)	(0.008)
Dummy variable	Year×Ind.	Year×Ind.
N	12303	12303
N of IVs	383	383
Hansen test (p-value)	0.845	0.895
Arellano-Bond test for AR(1). p-value	0.000	.
Arellano-Bond test for AR(2). p-value	0.238	0.076

Note: The dynamic capital investment models from equation (11) are estimated using the Blundell–Bond system GMM. The dependent variable is capital investment divided by total assets (INV). We use the firm-level uncertainty shock (FIRM) as the uncertainty shock (U). The indicators of cash-rich firms are dummy variables taking one when the ratios of cash holdings to total assets are in the 50th and 70th percentiles, respectively. Year×Ind. indicates the cross-terms of the time dummy and industrial dummy variables. The uncertainty shock, Year×Ind., and two- and three-lagged values of all the explanatory variables are used as instrumental variables. Standard errors are in parentheses. *, **, and *** represent the 10%, 5%, and 1% levels of significance, respectively.

Table **A: Information Criteria for Lag Selection:**

Corporate Investment:	Capital Investment			R&D		
Uncertainty Shock:	FIRM	VIXJ	EPUJ	FIRM	VIXJ	EPUJ
Zero-lag Model						
BIC	-1644.50	-1632.99	-1649.04	-1592.25	-1577.89	-1596.52
AIC	-204.99	-193.48	-209.53	-213.85	-199.49	-218.12
HQIC	-732.83	-721.32	-737.37	-721.68	-707.32	-725.95
One-lag Model						
BIC	-1459.98	-1470.01	-1490.14	-1533.14	-1559.39	-1563.03
AIC	-174.70	-184.74	-204.87	-191.01	-217.26	-220.9
HQIC	-645.98	-656.02	-676.15	-685.48	-711.72	-715.37
Two-lag Model						
BIC	-1425.18	-1442.87	-1414.06	-1490.52	-1520.18	-1484.6
AIC	-176.62	-194.31	-165.50	-184.66	-214.32	-178.75
HQIC	-634.44	-652.13	-623.32	-665.76	-695.42	-659.85
Three-lag Model						
BIC	-1392.86	-1394.28	-1393.12	-1476.48	-1498.41	-1468.42
AIC	-181.03	-182.45	-181.29	-206.9	-228.83	-198.84
HQIC	-625.38	-626.80	-625.64	-674.64	-696.57	-666.57

Note: We calculate three types of information criteria for the zero- to three-lag models, BIC, AIC, and HQIC, as shown in Appendix II.

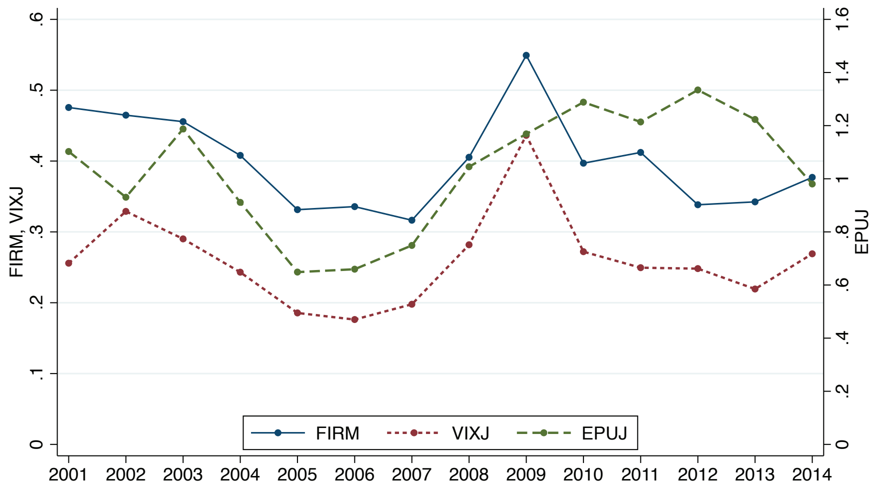


Figure 1: **Firm- and Macro-level Uncertainty Measures**

Note: The three lines show the sample average of the three uncertainty measures calculated in each fiscal year (horizontal axis). The solid line shows the firm-level idiosyncratic uncertainty (FIRM) calculated from the volatility in the daily excess equity returns of each firm on the left vertical axis, while the dotted line represents the VIXJ. The dashed line indicates the EPUJ on the right vertical axis. See Section 3.2.1 for the details on each of the uncertainty measures.

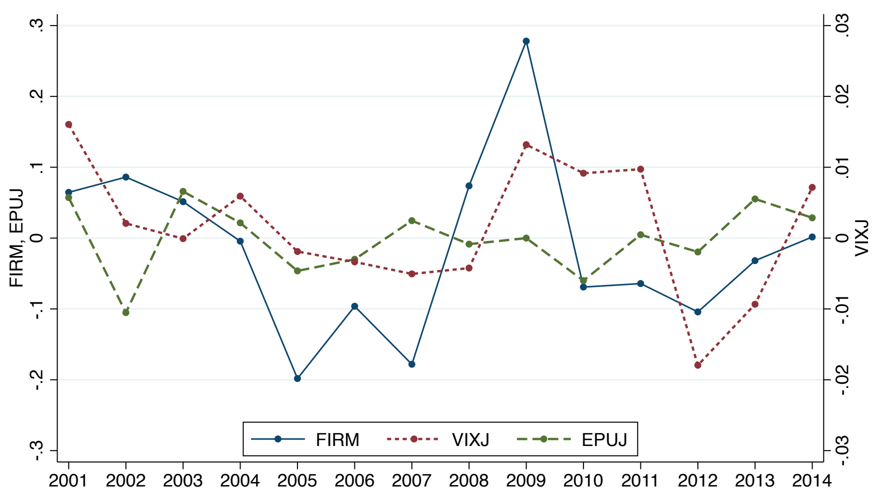


Figure 2: **Firm- and Macro-level Uncertainty Shocks**

Note: The three lines show the fiscal year-by-year sample average of the three uncertainty shocks. The solid line, dotted line, and dashed line respectively represent the firm-level uncertainty shock (FIRM; left vertical axis) and two macro-level uncertainty shocks extracted from the VIXJ (right vertical axis) and EPUJ (left vertical axis). See Section 3.2.2. and Appendix I for the details of each of the uncertainty shocks.

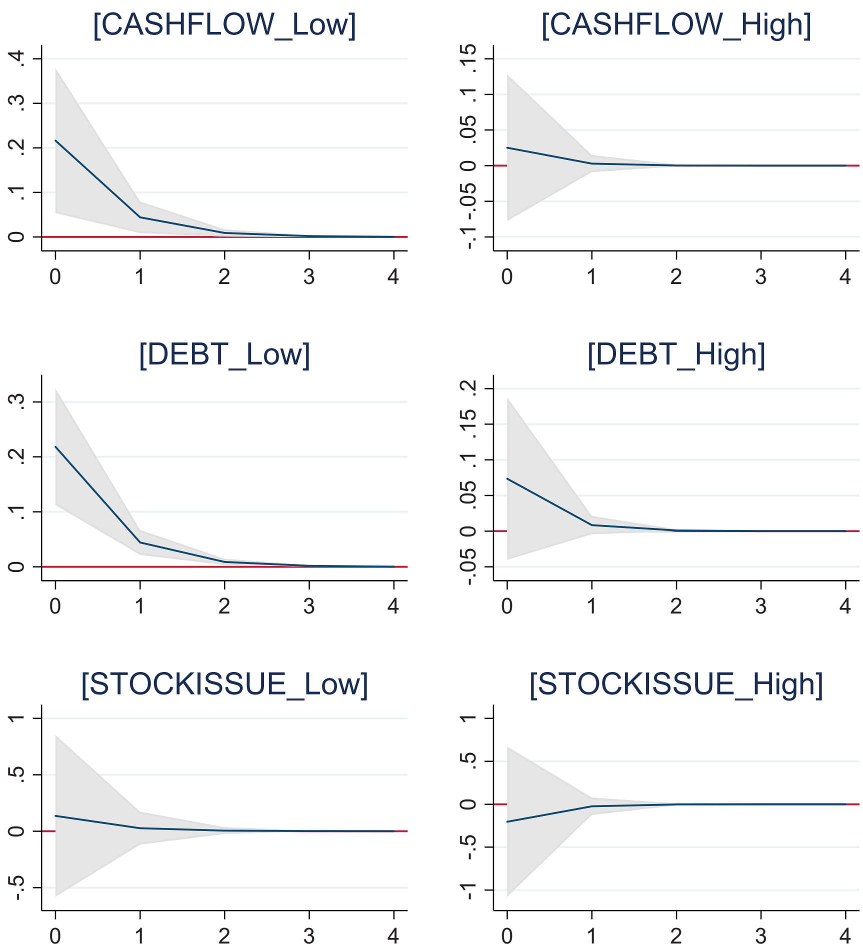


Figure 3: **Estimated Dynamic Response of Capital Investment**

Note: The solid line shows the dynamic response of capital investment to marginal changes in the financing variables, estimated using equation (9). This dynamic response is calculated based on the system GMM estimation results for the zero-lag model for capital investment. The horizontal axis corresponds to the four-period-ahead response in equation (9). "Low" indicates the estimated response to the low uncertainty shock, which is the 10th percentile value of the firm-level uncertainty shock, while "High" indicates that to the high uncertainty shock, which is the 90th percentile. The shaded area denotes the 90% confidence interval of the estimated response.

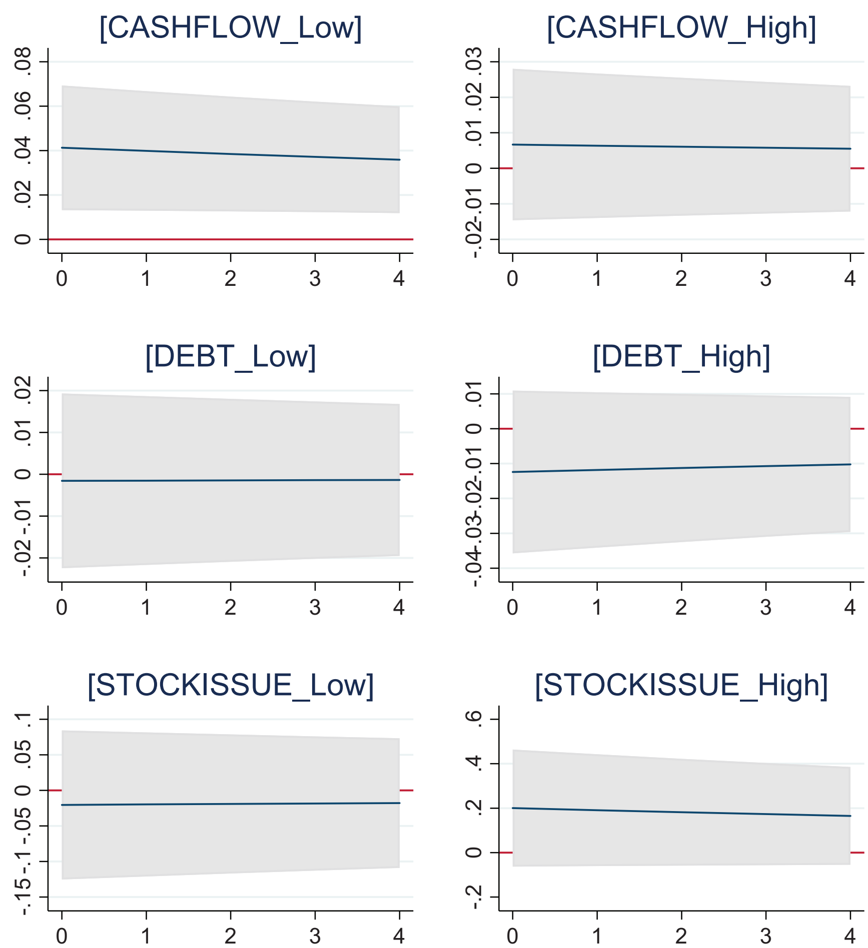
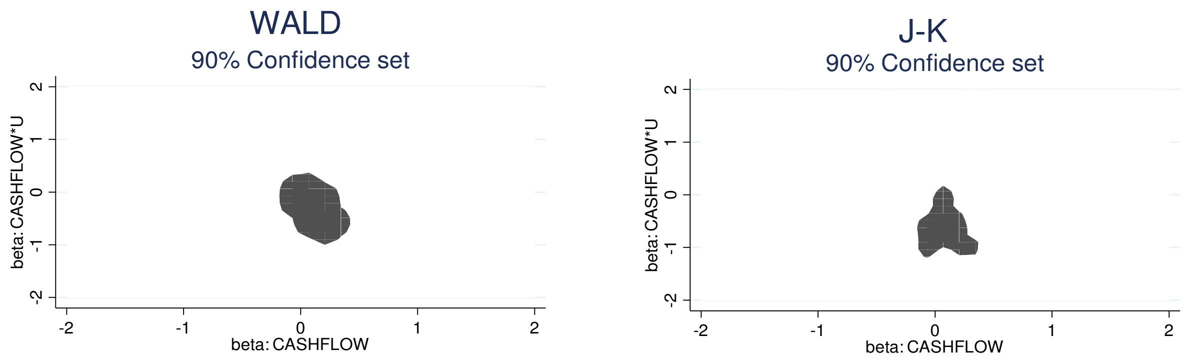
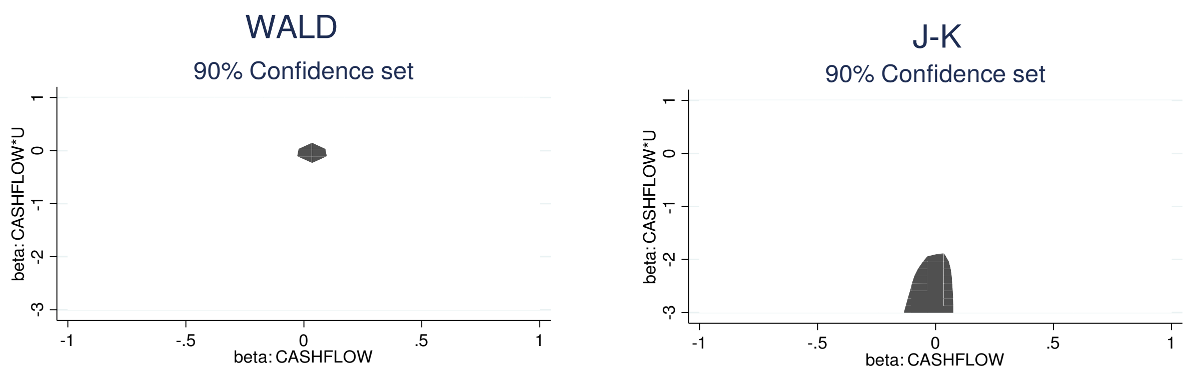


Figure 4: **Estimated Dynamic Response of R&D Investment**

Note: The solid line shows the dynamic response of R&D investment to marginal changes in the financing variables, estimated using equation (9). This dynamic response is calculated based on the system GMM estimation results for the zero-lag model for R&D. See also the note of Figure 3.



(a) Capital Investment



(b) R&D Investment

Figure 5: **Confidence Sets for Cash Flow and its Interaction Effects**

Note: The above figures present the projection-based confidence sets for the estimated coefficients on two endogenous regressors: cash flow (horizontal axis) and its interaction term with the uncertainty shock (vertical axis). The confidence sets are calculated based on the estimation results for the zero-lag model of capital investment (panel (a)) and R&D investment (panel (b)) including the firm-level uncertainty shock (FIRM). See Tables 2 and 3 for these estimation results. The confidence sets are robust to weak instruments under the assumption that the coefficients on the other endogenous regressors are strongly identified. The number of grid points searched is $30^2 = 900$. The shaded areas for "Wald" and "J-K" show the pairs of hypothesized values for the two coefficients that are not jointly rejected by the Wald and J-K (Kleibergen, 2005) tests.

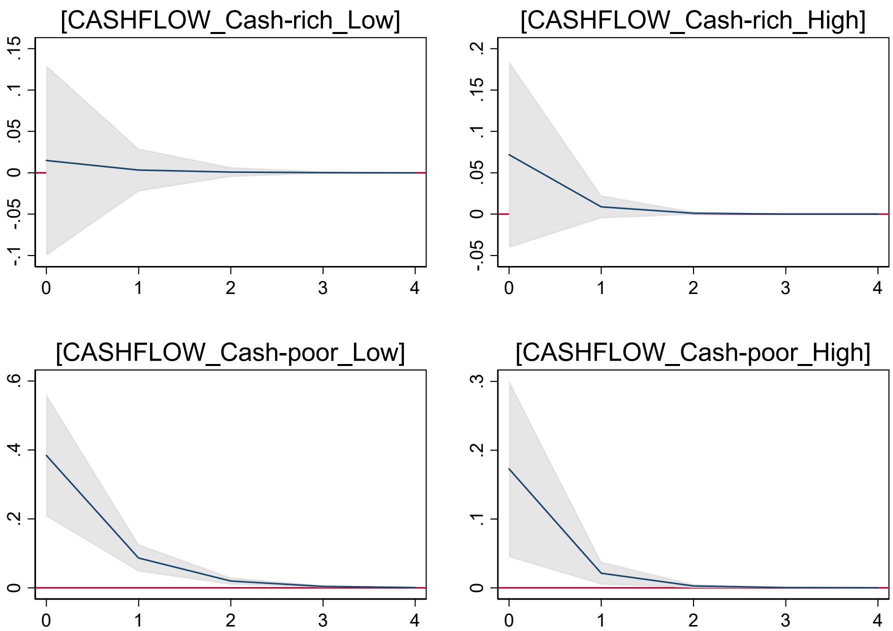


Figure 6: **Estimated Dynamic Response of Capital Investment in Cash-rich and Cash-poor Firms**

Note: The solid line shows the dynamic response of capital investment to marginal changes in the variable of cash flows, estimated using equation (9) with the interaction term of cash flow and the indicator variable of cash holdings. Cash-rich firms are defined by the top 50th percentile of cash holdings to total assets, while cash-poor firms have the lower ratio of the 50th percentile. This dynamic response is calculated based on the system GMM estimation results for the zero-lag model for capital investment. The horizontal axis corresponds to the four-period-ahead response in equation (9). "Low" indicates the estimated response to the low uncertainty shock, which is the 10th percentile value of the firm-level uncertainty shock, while "High" indicates that to the high uncertainty shock, which is the 90th percentile. The shaded area denotes the 90% confidence interval of the estimated response.

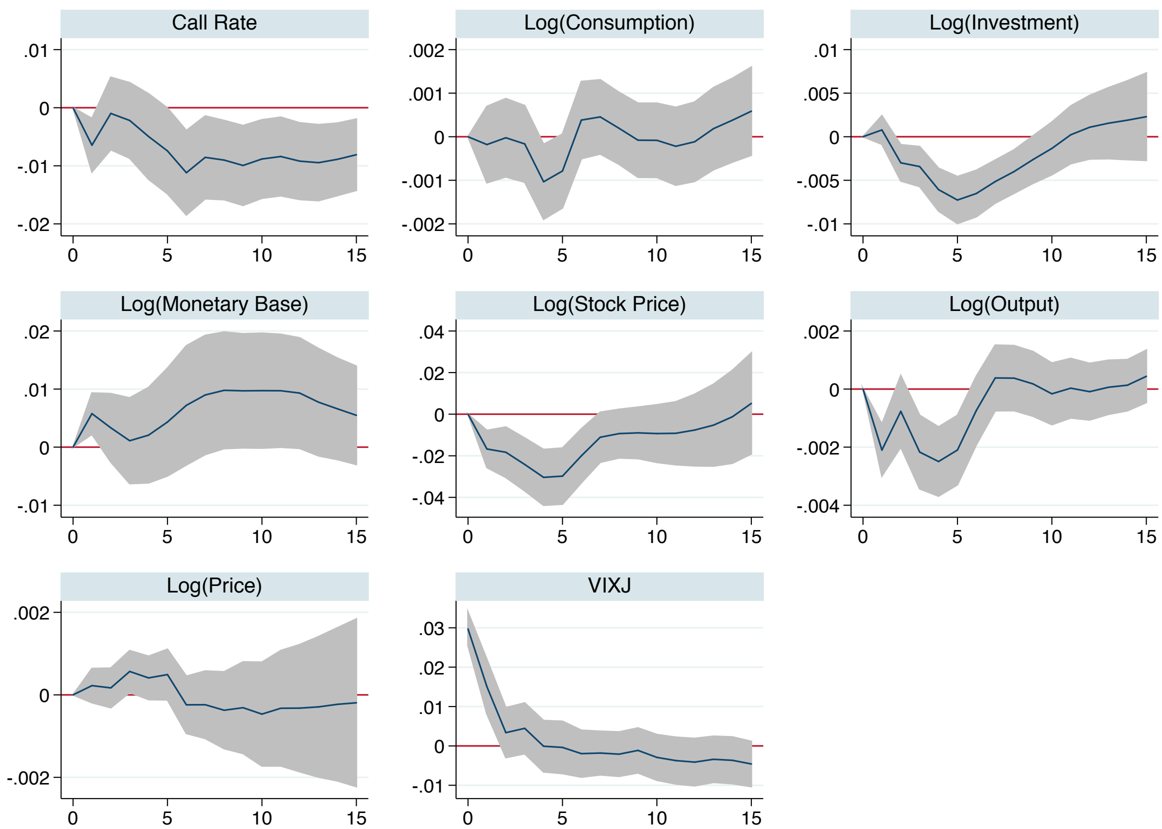


Figure A: **Impulse Responses to the Uncertainty Shock**:

Note: The solid lines show the impulse responses to a one-standard-deviation uncertainty shock and the shaded areas are the 90% confidence intervals.